ANSWERS: Hess's Law

1. $\Delta_c H°$ $= \Sigma\Delta_f H°$ (products) $- \Sigma\Delta_f H°$ (reactants)

$= [(5 \times -394) + (6 \times -286)] - [-295]$

$= -3686 + 295$

$= -3391$ kJ mol^{-1}

2. $\Delta_r H° = \Sigma\Delta_f H°$ products $- \Sigma\Delta_f H°$ reactants

$= (-314) - (-46 + -92)$

$= -176$ kJ mol^{-1}

3. $\Delta_c H° = \Sigma\Delta_f H°$ (products) $- \Sigma\Delta_f H°$ (reactants)

$= [(5 \times -394) + (6 \times -286)] - [-295]$

$= -3686 + 295$

$= -3391$ kJ mol^{-1}

4. Desired equation is:

– 2EqA + 3EqB + 2EqC – 6Eq4

$4NH_3(g) \rightarrow 2N_2(g) + 6H_2(g)$ $\Delta_r H = +184$

$6H_2(g) + 3O_2(g) \rightarrow 6H_2O(g)$ $\Delta_r H = -1452$

$2N_2(g) + 2O_2(g) \rightarrow 4NO(g)$ $\Delta_r H = +360$

$6H_2O(g) \rightarrow 6H_2O(l)$ $\Delta_{vap} H = -246$

$2 \times 92 - 3 \times 484 + 2 \times 180 - 6 \times 41$

$= 184 - 1452 + 360 - 246$

$= -1154$ kJ mol^{-1} (-1150 kJmol^{-1} 3 sig fig)

5. $\Delta_c H° = \sum\Delta_f H$(products) $- \sum\Delta_f H$(reactants)

$=[(10 \times -393) + (11 \times -286)] - (-250)$

$= -6\,826$ kJ mol^{-1} or $(-6\,830$ kJ mol$^{-1})$

6. (i) $3H_2O + 2CO_2 \rightarrow C_2H_5OH + 3O_2$ +1367

$2C + 2O_2 \rightarrow 2CO_2$ -394×2 (788)

$3H_2 + 1½O_2 \rightarrow 3H_2O$ -286×3 (858)

$½\ O_2 + 2C + 3H_2 \rightarrow C_2H_5OH$ -279 kJ mol^{-1}

(ii) The enthalpy change would be more positive.
Heat energy is absorbed when converting a liquid to a gas. Therefore if the ethanol formed were in the gaseous state, less energy would be released in its formation / products would have a higher enthalpy.

7. $2Zn + 2S \rightarrow 2ZnS$ 2 (200)

$2Zn + O_2 \rightarrow 2ZnO$ 2 (–348)

$2S + 2O_2 \rightarrow 2SO_2$ 2 (–297)

–890 kJ mol^{-1}

OR

$\Delta_r H° = \Sigma\ \Delta_f H°_{products} - \Sigma\ \Delta_f H°_{reactants}$

$= 2\ (-348) + 2\ (-297) - 2\ (-200)$

$= -890$ kJ mol^{-1}

8. $\Delta_r H° = \Sigma\Delta_f H°$*(products)* $- \Sigma\Delta_f H°$*(reactants)*

$-4163 = 6 \times (-393) + 7 \times (-286) - \Delta_f H°(C_6H_{14}, \ell)$

$\Delta_f H°(C_6H_{14}, \ell) = \{6 \times (-393) + 7 \times (-286)\} + 4163$ = **(-2358 – 2002) + 4163**

$\Delta_f H°(C_6H_{14}, \ell) = -197$ kJ mol^{-1}
(could use manipulation of equations – Hess's Law) second set of values apply)

9. Desired Equation = EqA – $\frac{1}{2}$ EqB – 2EqC + 3EqD

$(NH_2)_2CO(s) + 3\frac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(\lambda) + 2NO_2(g)$ $\quad \Delta_r H = -632$

$2NO(g) + 3H_2O(g) \rightarrow 2NH_3(g) + 2\frac{1}{2}O_2(g)$ $\quad \Delta_r H = +453$

$2NO_2(g) \rightarrow 2NO(g) + O_2(g)$ $\quad \Delta_r H = +114$

$3H_2O(\lambda) \rightarrow 3H_2O(g)$ $\quad \Delta_{vap} H = +123$

$(NH_2)_2CO(s) + H_2O(l) \rightarrow CO_2(g) + 2NH_3(g)$

$\Delta_r H = \Delta_r H$ (EqA) – $\frac{1}{2}\Delta_r H$ (EqB) – $2\Delta_r H$ (EqC) + $3\Delta_{vap} H$(EqD)

$= -632 + \frac{1}{2}906 + 2 \times 57 + 3 \times 41$

$= -632 + 453 + 114 + 123 = 58$ kJ mol^{-1}

10. Desired Equation:

$C_2H_2(g) + 2\frac{1}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$

$\Delta_c H^o = \sum \Delta_f H°$ (products) – $\sum \Delta_f H°$(reactants)

$= 2\Delta_f H°(CO_2) + \Delta_f H°(H_2O) - \Delta_f H°(C_2H_2) - \Delta_f H^o(O_2)$

$= 2 \times (-393) + (-285) - (+229) - 0$

$= -1300$ kJ mol^{-1}

OR Desired Equation:

$C_2H_2(g) + 2\frac{1}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$ $\quad \Delta_c H^o = ?$

I: $2C(s) + H_2(g) \rightarrow C_2H_2(g)$ $\quad \Delta_r H°(I) = 229$ kJ mol^{-1}

II: $H_2(g) + -O_2(g) \rightarrow H_2O(l)$ $\quad \Delta_r H°(II) = -285$ kJ mol^{-1}

III: $C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta_r H°(III) = -393$ kJ mol^{-1}

-I: $C_2H_2(g) \rightarrow \cancel{2C(s)} + \cancel{H_2(g)}$ $\quad -\Delta_r H°(I) = -229$ kJ mol^{-1}

II: $\cancel{H_2(g)} + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\quad \Delta_r H°(II) = -285$ kJ mol^{-1}

2III: $\cancel{2C(s)} + 2O_2(g) \rightarrow 2CO_2(g)$ $\quad 2\Delta_r H°(III) = -786$ kJ mol^{-1}

$C_2H_2(g) + 2\frac{1}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$ $\Delta_c H° = -1300$ kJ mol^{-1}

11. $C_2H_5OH(l) + 3O_2(g) \rightarrow 3H_2O(l) + 2CO_2(g)$

$3 \times \Delta_f H°(H_2O, l) + 2 \times \Delta_f H°(CO_2, g) - \Delta_f H°(C_2H_5OH, l) = -1367$ kJ

$\Delta_f H°(C_2H_5OH, l) = -858 - 788 + 1367$

$= -279$ kJ mol^{-1}

Alternative Using Hess Law

$C_2H_5OH(l) + 3O_2(g) \rightarrow 3H_2O(l) + 2CO_2(g)$ $\Delta_c H° = -1367$ kJ mol^{-1}

hence

x2 $C + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta_f H° = -788$ kJ mol^{-1}

x3 $H_2(g) + 1/2O_2(g) \rightarrow H_2O(l)$ $\quad \Delta_f H° = -858$ kJ mol^{-1}

reverse $3H_2O(l) + 2CO_2(g) \rightarrow C_2H_5OH(l) + 3O_2(g)$ $\quad \Delta_c H° = +1367$ kJ mol^{-1}

hence $\Delta_f H°(C_2H_5OH, \lambda) = -279$ kJ mol^{-1}